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The use of biological means to treat waste has been a mainstay of industrial and municipal wastewater treatment technology. Recovery of waste materials or conversion to other economically useful forms of commercial products has provoked considerable scrutiny but few genuine commercial processes. This lapse of application is partially attributable to the changing knowledge base supporting such ventures and the economic recovery of development costs. The increasing cost of materials and the enforcement of environmental legislation has paved the way for a renewed interest in biological technology that offers both a recovery of unused resources and a general reduction of waste effluents.

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Examples of
Biological Waste Minimization Technology

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The use of biological means to treat waste has been a mainstay of industrial and municipal wastewater treatment technology. Recovery of waste materials or conversion to other economically useful forms of commercial products has provoked considerable scrutiny but few genuine commercial processes. This lapse of application is partially attributable to the changing knowledge base supporting such ventures and the economic recovery of development costs. The increasing cost of materials and the enforcement of environmental legislation has paved the way for a renewed interest in biological technology that offers both a recovery of unused resources and a general reduction of waste effluents.

INTRODUCTION

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There are several examples of the application of biological technology to the minimization of waste. This paper narrows the focus to two specific technologies. The first is the utilization of cheese whey as a feedstock for conversion to fuels, edible biomass and flavor constituents[1]. This technology has taken a major waste problem found in the dairy industry and has now a commercial plant employing biological conversion to saleable products in operation. A second example of biological waste minimization is found in the wood and paper industry where biopulping is now considered an economic possibility[2]. This development utilizes lignin degrading organisms to delignify wood chips for mechanical pulping operations followed by chemical bleaching. When contrasted with existing pulping technologies, biopulping offers improvement in paper quality and a major reduction to pulping waste effluents.

WHEY POLLUTION

The residual liquid derived from the processing of milk to form cheese after fat and casein have been removed is called whey[3]. On average, for each pound of cheese produced, nine pounds of whey are formed. Whey composition varies depending on the variety of cheese produced[4]. Usually whey contains 6.5 to 7.0% solids that are largely composed of lactose (milk sugar). Proteins, lactic acid, fat, minerals and vitamins are among the other minor components.

Whey poses a major waste treatment problem for the world-wide dairy industry due to its high biochemical oxygen demand. Roughly 50% of the whey is discarded world-wide. The remainder is processed for value added products. Lactose derived

from whey production is 4.4 million tons of which 0.2 million tons is used commercially. Surplus lactose is discharged to a variety of treatment plants but represents a significant loss of potential food and energy. As a source of pollution, whey processing imposes a significant biochemical oxygen demand of 30,000 to 50,000 ppm on wastewater treatment plants for every two pounds of cottage cheese produced. When based on cottage cheese production, whey discharge equals 20% by weight of the cheese production. The pollution load when scaled on a small creamery (1000 gal./day), the discharge is equivalent to that of 1800 people[5].

There is increased demand for cheese by the world- wide population. In 1981, the United States accounted for 18% of the total cheese manufacture with production figures of 2.1 cheese, 19.9 whey, 1.25 whey solids, and 0.15 whey protein in the millions of tons.

Treatment technologies are available but are considered economically non-viable. For instance, in the United States, treatment costs have been estimated at 0.6-4.4 cents per pound of cheese produced. Future environmental controls that tighten discharge limitations loom as economic threats to the dairy industry.

WHEY AS A FOOD SOURCE[6]

In the U.S., whey solids are equally used as human food and animal food. The processing of whey can yield a plethora of useful food products (Table 1). Of these varied processes leading to product recovery this paper will focus on the development of a whey conversion process involving the formation of yeast biomass from lactose utilizing yeasts. The importance of this process is that there is a commercially operating plant showing the profitability of this waste reclamation.

WHEY CONVERSION APPLICATION(Yeast Biomass Fermentation)[7]

A process based on the fermentation of whey with the yeast *Kluveromyces fragilis* forms an inactive dried yeast biomass as product. The product is a non-hygroscopic free flowing powder having a light yellow- brown color, and a clean yeast aroma and flavor. In addition to the yeast biomass, the process can be made to produce a whey protein product of 35-80% protein content and high calcium whey material. A plant producing this food material is located in Hanford, California.

YEAST BIOMASS FERMENTATION[8,9]

During yeast fermentation, lactose is converted to yeast biomass. Lactose is hydrolyzed by the enzyme beta- D-galactosidase found in yeasts *Kluveromyces fragilis* or *K. lactis* or from the fungus *Aspergillus niger* or *Bacillus sp.* and *Streptococcus thermophilis*. After completion of the sugar conversion, yeast cells are harvested by centrifugation of the fermentation broth. The separated yeast cream is then spray dried to a powder form containing 5-10% moisture with shelf life of approximately one year under specified conditions. The raffinate is lactose free whey and is used as a cattle feed supplement.

The plant receives 6,000 gal shipments of raw whey. The raw whey is transferred to a heat exchange system for pasteurization. The pasteurized whey is charged into a 25,000 gal. fermentor for final conversion to yeast biomass.

The yeast biomass is seen to have utility as an ingredient in spice/seasoning blends, snack foods, food flavor extract, soup and gravies, smoke flavoring, meat products, meat analog, salad dressings, processed cheese and cheese products such as spreads. Animal feed applications are as a protein source, as a vitamin and nutrient supplement, and as a source of biologically active factors.

PULP PRODUCTION POLLUTION[10]

Objectionable waste streams and airborne effluents are generated from wood pulping operations. In the United States, some 286 mill locations generate about 60 million tons of wood-derived pulp. Each year, these plants use about 2 trillion gallons of water for a variety of processing steps. Process dependent requirements for pulp plants are some 34,604 gal. water per ton of Kraft pulp and 62,617 gal. per ton of sulfite pulp. Plant performance in controlling effluents is a function of age and installation of abatement technology. Due to the heavy pollution loads of these processes, interest has been generated in new means of controlling waste at the source through process change.

BIOPULPING[11,12]

A major effort is underway to investigate the use of wood degrading fungi as biological means to delignify pulp in certain pulping operations. Mechanical pulps are seen as a possible target for the application of biopulping for process improvement through product improvement, reduction of chemical processing steps, and process effluent reduction[13].

Saprophytic microorganisms account for the continuous degradation of carbonaceous plant materials in nature. Wood materials are degraded largely by the higher fungi[14]. Spores and hyphae permit the fungi to infect wood. In fact the organization of the hyphae of these fungi contributes to the ability to penetrate wood cells. The decay process involves specific enzymes that are secreted from the hyphae and are integral to wood cell wall attack. White-rot fungi are a grouping of wood degrading microorganisms exhibiting exceptional abilities to degrade lignin[16,17]. The physiological requirements supporting lignin metabolism have been studied in some detail for the white-rot fungus Phanerochaete chrysosporium[18]. In addition to known fungi, collections have been assayed to determine new organisms supporting lignin decomposition. The fungi investigated in these studies show a variety of abilities for lignin degradation, although none have been shown to support growth entirely by lignin breakdown.

Mechanical pulps are used to produce paper products demanding exceptional optical properties when compared with other pulp processes. The paper products produced by mechanical pulping have high opacity and light scattering. The utility of mechanical pulps are limited by the the strength properties of pulp derived from only certain softwoods and low-density hardwoods, and the need to

blend pulps to improve low-strength properties. White- rot fungi have been proposed as a biological pretreatment of wood chips prior to mechanical pulping or as a post- treatment for the mechanical pulp itself. Studies investigating the use of two white-rot fungi (Phanerochaete chrysosporium, and Dichomitus squalens) as a pretreatment of wood chips to reduce lignin content have shown an improvement in strength characteristics, brightness and light-scattering coefficients were both decreased but opacity was not adversely affected.

CONCLUSIONS

The two examples used to make the point of the importance of biotechnology to waste minimization are only a start. Resource recovery and enhanced product performance are important to the survival of both technology examples. The ability of certain commercial sectors to develop such technology is severly constrained by market conditions in a manner that may diminish the part that industry can play in such endeavors. The application is often seriously affected by the correct matching of wastestreams and upstream processing. Resource recovery or conversion is an important part to the overall feature supporting these waste control ventures. While the wastes targeted with these two examples are quite large and important to the world economy, there are a wide number of opportunities awaiting sucessful development.

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TABLE 1. WHEY CONVERSION PROCESSES[5]

PROCESS	PRODUCT
Whey Liquids (whole)	
Condensed and dry whole whey	Human Food
	Animal Feed
Demineralized Whey	Protein Based Infant Food
Refined Lactose	Edible Lactose
	Delac (animal feed)
Ultrafiltration for Whey Protein Concentrate	Whey Protein Concentrate(WPC) (Edible Protein)
	Whey Permeate (Commercially Processed) -Refined Lactose
	-Lactose Hydrolyzed Products -Fermentation Products